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GB A 2147141 GB A 2111299 GB 1055012
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(54) Electron beam apparatus

(57) Apparatus suitable for exposing a pattern on an electron resist material in integrated circuit manufacture focusses the light image of an appropriately patterned reticle on to a photocathode 4, the emitted electrons being focussed on the workpiece 9. The pattern may be reduced in size by either or both of the light and electron optical systems. Alignment of the electron image with the workpiece is achieved by using an alignment mask 14 and deflecting the electron beam in response to backscattered electrons from the workpiece. The workpiece may be carried on a movable table controlled by a step and repeat system. The electrons emitted from the photocathode are extracted and accelerated by a planar grid 7 (and Fig. 2) parallel to the photocathode, the grid being moved in its plane during exposure of the resist to eliminate shadows due to the grid elements.

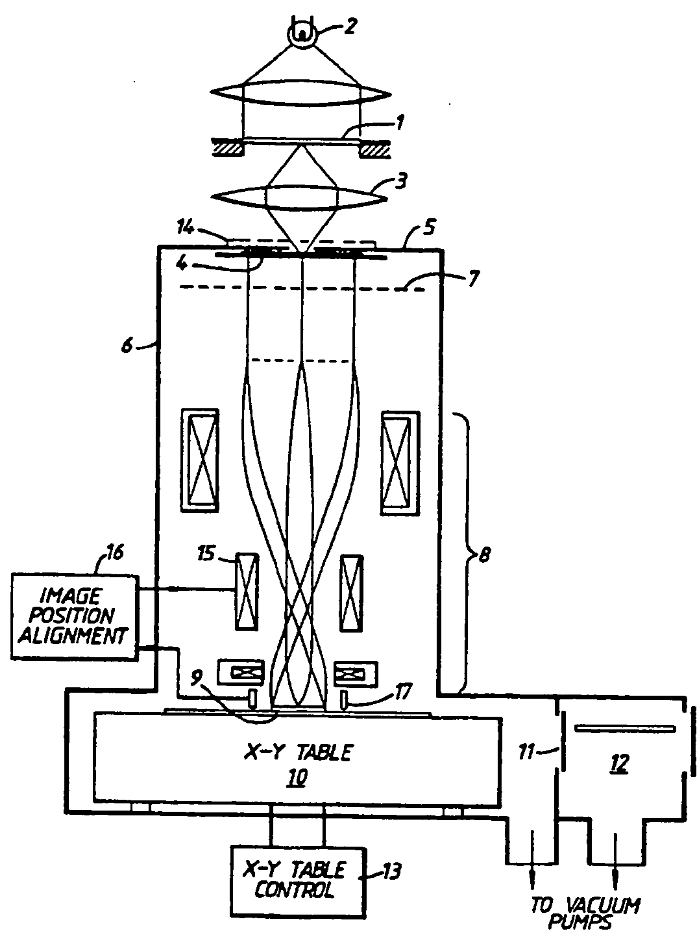

FIG. 1.

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The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

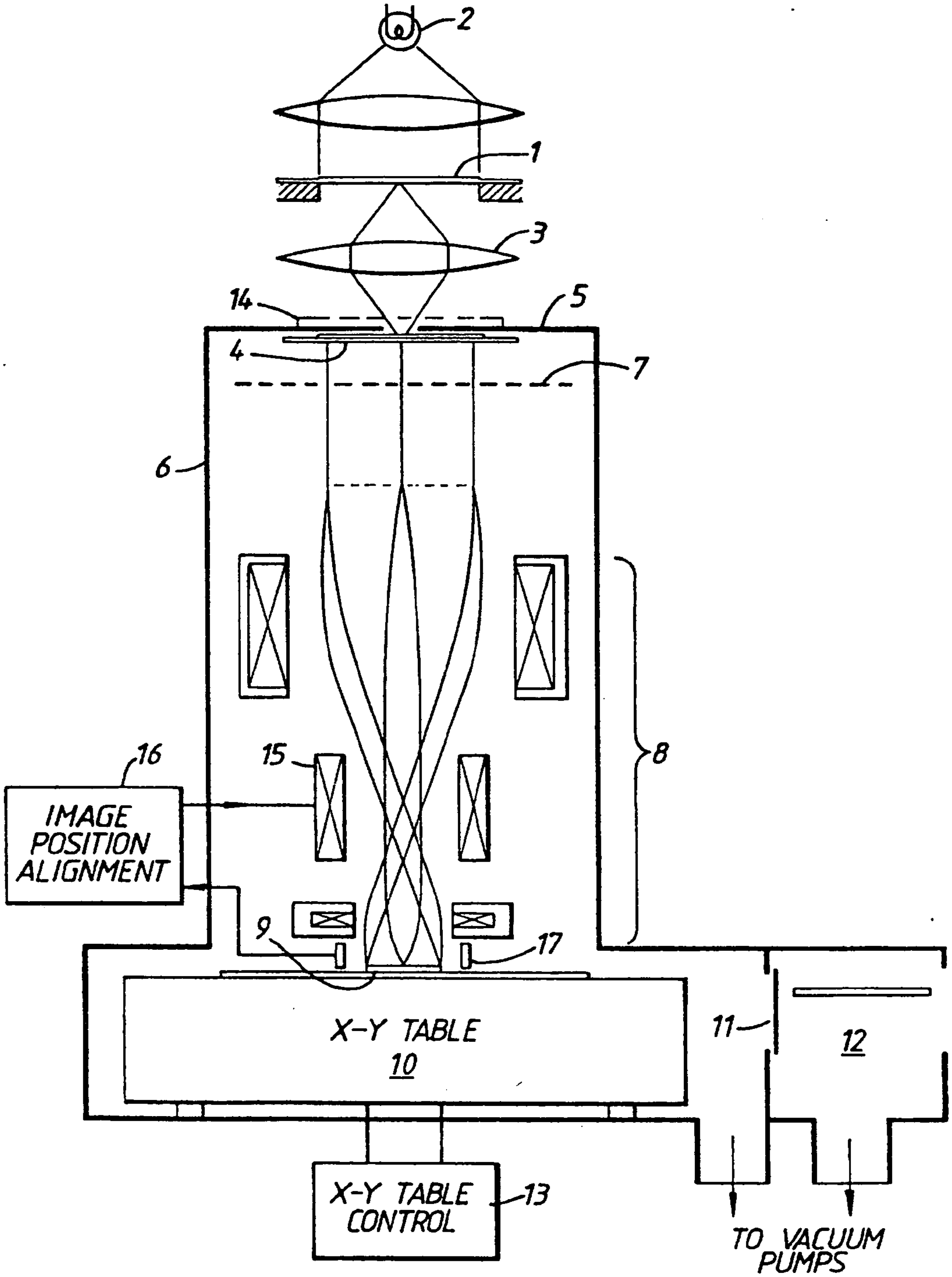
2
1
3
14
5
4
7
6
8
16
IMAGE POSITION ALIGNMENT
15
9
17
X-Y TABLE
10
11
12
X-Y TABLE CONTROL
13
TO VACUUM PUMPS

FIG. 1.

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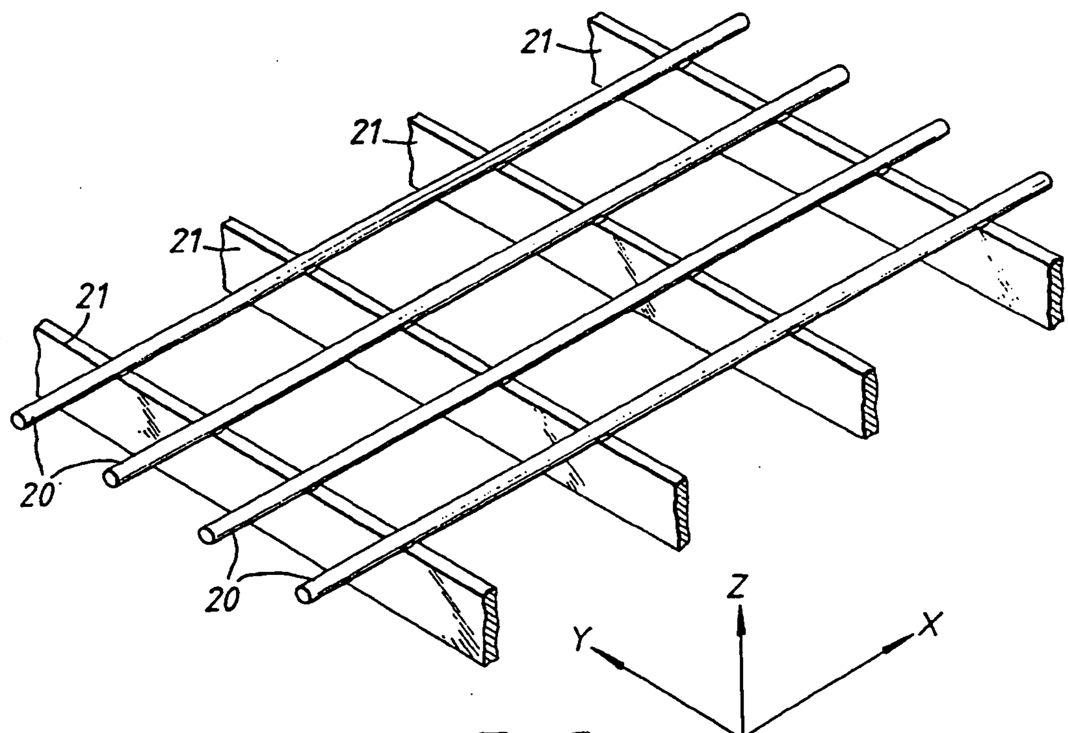

FIG.2.

SPECIFICATION

Electron beam apparatus

This invention relates to electron beam apparatus which is especially, though not exclusively, suited to the exposure of patterns on resist materials in the manufacture of integrated circuits.

In the manufacture of integrated circuits the accuracy reguired in the patterning of resist materials used as masks is, in some instances, so high that the blurring of light images due to the wavelike nature of light is unacceptably large, even with the use of ultraviolet light. In order to obtain high enough accuracy use has been made of electron beams because images in electron beams do not suffer from the same blurring as light images, but it is more difficult to produce pattern images using electrons. One way in which this problem has been tackled is to produce the reguired image sequentially by deflecting an electron beam focussed to a spot along a suitable path to describe the image, but this approach is very time consuming because the path must necessarily be very complicated and the need for accurate control of the beam means that it cannot be deflected rapidly. It is plainly quicker to use an arrangement which produces the whole electron beam image at once, but this is a problem in itself because whereas a light mask can be produced using suitable opaque materials on a translucent support, there is no suitable support material which is transparent to electrons. Stencil masks have been used either to shape an electron flood beam or built into a photocathode to produce a pattern of light for energising it but such means are expensive to make and very difficult to alter.

It is an object of the invention to provide an electron beam apparatus suitable for exposing patterns on resist materials for the manufacture of integrated circuits which avoids the difficulties described above and moreover enables a conventional light mask to be used.

According to the present invention there is provided an electron beam apparatus including an evacuated envelope containing an area photocathode, electron lens means and a workpiece, the electron lens means being arranged to focus on the workpiece an image of electrons emitted by the photocathode, an illuminated mask and an optical lens for focussing on the photocathode a light image of the pattern of the mask, thereby to cause the mask pattern to be exposed on the workpiece by an electron beam.

The electrodes from the photocathode may be extracted and accelerated by a planar electrode of fine wires, possibly supported at intervals by transverse strips to the edges of which the wires are attached. This electrode may be continuously mov d in its own plane so that the shadow of the wires does not affect the exposure of the workpiece. The optical lens may be arranged to produce a light image on the photocathode of the same size as the mask or it may produce an image of reduced size. The photocathode may be substantially planar and formed as a coating inside an end wall of the envelope.

The electron lens may be arranged to reduce the size of the optical image in producing the electron image, so that a light image of adequate size to provide the required resolution may be used and the electron optics reduces the size to that required on the workpiece.

The pattern mask may be a conventional 5x or 10x glass or quartz reticle such as would be used for exposure of resist materials using light, and it may have a finer pattern on it than could be produced at its correct size clearly enough by light. It may, of course, be of larger size with the penalty that the size of the apparatus would be similarly increased. The reduction in size produced by the electron lens means should be by a factor of 5 or 10 or as appropriate to produce the required final electron image size.

The electron lens means may be arranged to extract and accelerate the electrons from the photocathode so that the electrons acquire sufficient energy to perform the bombardment with a weak or zero electrostatic field near the workpiece.

The workpiece may be mounted on a carrier which may be part of a conveyor belt system. An air lock may be provided to enable the workpiece to be carried into and out of the evacuated envelope with a minimum amount of air leakage into the envelope. For many types of photo-cathode exposure to the atmosphere is undesirable and the air lock should be arranged with this in mind.

The carrier for the workpiece may be arranged to be moved a number of positions within the envelope so that the same mask pattern can be exposed on a number of different areas of a workpiece, which may be, for example, an entire semiconductor slice.

Electrons emitted by the workpiece in response to the bombardment by part of the electron image may be used to monitor or correct the position of the electron image on the workpiece either before or during the exposure of the workpiece to the whole electron image.

The w rkpiec may be mount d on a movable table for the initial placing of the workpiece relative to the electron image and the subsequent stepping to enable the electron exposure to be repeated at different positions on the workpiece.

In order that the invention may be fully understood and readily carried into effect an embodiment of it will now be described in greater detail with reference to the accom-

panying drawings, of which:

FIGURE 1 is a diagram of one example of apparatus according to the invention; and

FIGURE 2 shows part of the electron extraction electrode of the apparatus of Figure 1.

Referring to Figure 1, the mask pattern 1, typically a conventional 5x or 10x glass or quartz reticle, is illuminated by a lamp or other suitable source of illumination 2 and an image of the pattern is focussed by a light lens system 3 on to a photocathode 4. The photocathode 4 is mounted or formed on a substantially plane, transparent face plate 5 forming part of an evacuated envelope 6, the photocathode being inside the envelope and held at a suitable potential, say -50 kV, relative to the workpiece. The photocathode 4 is translucent so that the light image of the pattern causes electrons to be emitted into the envelope where they are extracted from the vicinity of the photocathode 4, and accelerated by a planar extractor grid 7 to form an image in electrons. The electron image is refocussed at a smaller size by a telecentric electron lens system 8 on a workpiece 9, e.g. a semiconductor slice with a coating of an electron bombardment sensitive resist, mounted on an XY table 10 which is held at ground potential, the electrical connections and supplies for these components are not shown. The lens system 9, which may include electrostatic and/or magnetic lenses, accelerates, to for example 50 KEV, the image in electrons emitted by the photocathode 4 and focusses it on the workpiece 9.

In order to enable the transporting of the workpiece 9 into and out of the envelope 6 a door 11 leading to an air lock 12 is provided in the wall of the envelope 8. Since many photocathode materials are easily damaged by contact with air the operation of the air lock 12 is arranged to reduce the likelihood of contamination of the photocathode. When the workpiece 9 is being placed in the envelope 8 through the door 1 the air lock 12 is evacuated by a vacuum pump (not shown).

In one example of the invention the light optical system is arranged so that the image formed on the photocathode 4 is of the same size as the mask pattern 1, and a linear reduction in electron image size may be produced by the electron lens system 8, chosen to match the factor by which the mask pattern is oversize relative to the pattern required to be exposed on the workpiece 9. Alternatively, the light optics may provide all or part of any size reduction required, bearing in mind the inherent minimum size limitations due to the wavelength of the light.

Typically, the workpiece 9 is part of a semiconductor slice with a coating of an electron sensitive resist to be patterned as a step in a process of manufacturing an integrated circuit on the semiconductor material. The pattern to be formed may have features in 0.1 to 1.0 micron size range which cannot be produced using light imaging (even using ultra-violet light) because of the wavelike nature of light. However, if the mask pattern 1 and its light image on the photocathode 4 are 5, 10 or more times larger in size light imaging can be used satisfactorily, with the remaining size reduction effected by the electron optics.

The apparatus is constructed so as to be capable of successively exposing a plurality of areas on all or a large part of a slice or wafer of semiconductor material, by providing a stepping mechanism formed by the X-Y table 10 and its control unit 13 to move the workpiece 9 to a succession of positions for each exposure. The X-Y table may have a high accuracy measurement system, for example using laser interferometry or a moire fringe counter, to enable its accurate location. Of course, different mask patterns can be employed for exposing different areas of the slice and means may be provided for automatically changing the pattern 1 as required. Apparatus may be provided to enable the timing of the electron exposure of the workpiece to be controlled to high accuracy, for example, by switching the voltage on the extractor grid 11.

Alignment of the workpiece with the electron image is achieved by detecting secondary or backscattered electrons from the workpiece when a special alignment mask 14 is used to produce the image or to blank out all but specific parts of an image. The alignment mask 14 may be placed on the face plate 5 as shown, which placement requires that the light image of the reticle be accurately aligned with it. In an alternative arrangement which brings the light optical system into the alignment control loop, the mask 14 is located adjacent to or instead of the reticle 1. The workpiece itself may be provided with grooves or mesas (ridges) which produce characteristic secondary or backscattered electron signals during the alignment process. The electron optics includes an X-Y deflection system 15, e.g. coils, with an image position alignment system 16 responsive to secondary or backscattered electrons from the workpiece 9 and picked up by detectors 17 to provide fine adjustment of the position of the electron image on the workpiece. Feedback may be provided from the table position measurement system or the registration system to the deflection system to correct for movement of the table or workpiece during electron exposure. The planar extractor grid 7 should provide a uniform electric field gradient over entire area of the photocathode 4 so that the electrons emitted are drawn away from the photocathode and accelerat d downwards parallel to the axis of the electron lens system 8. In this way the accuracy of the electron image at the entry of the electron lens system 8 is maintained. The form of construction of the grid 7 used is shown in Figure 2 and consists of a large

number of fine metal wires 20 extending parallel to one another in the plane of the grid. The wires 20 are supported at intervals by being welded to the edges of transverse metal strips 21. The structure is supported on a rigid perimeter frame (not shown) to which the ends of the wires 20 and the strips 21 are secured. The wires and strips are preferably held in tension so as to reduce their deflection under electrostatic forces. The wires have a diameter of about 50 microns and are spaced at intervals of 0.5 to 1 mm. The strips have a width of about 500 microns and a thickness of about 50 microns and are spaced at intervals of about 1 cm.

The grid 7 is of at least the same size as the phtotocathode 4, is parallel to it with a distance between them of about 2 cms and is maintained (except during blanking of the electron image) at a potential of some 50,000 volts positive with respect to it when the apparatus is in operation. The wires and strips of the grid 7 will cause shadows in the electron image and to eliminate the effect of these, which interferes with the correct reproduction of the light image of the pattern mask 1 as an electron image, the grid 7 is rotated and/or orbited so that it is moved in both the X and Y directions (transverse to the strips and transverse to the wires) during the exposure of the resist. The speed and amplitude of the movement is chosen to be suitable to remove the effect of the shadows on the exposure of the resist.

Although the electric field gradient will be uniform in most of the region between the photocathode 4 and the grid 7, there are two ways in which distortions will arise near the grid itself. Because the grid 7 is made up of parallel wires the equipotential surfaces near the wires will follow cylindrical waves parallel to the wires, and these waves will act as cylindrical electron lenses. The large potential difference between the wires and the photocathode will cause significant electrostatic forces on the wires which will tend to bend towards the photocathode. The strips, being stiffer parallel to the axis of the apparatus, will not be deflected appreciably and if sufficiently closely spaced along the wires will stabilise them against excessive bending. Since electrons leaving the photocathode 4 will have been accelerated by the electric field it is thought that when passing through the grid 7 they will have acquired sufficient speed not to be deflected very much by the field distortions just mentioned.

Although the invention has been described with reference to only a single embodiment it will be appreciated that many changes could be made to that embodiment without departing from the invention. For example, the structure of the extractor grid 7 could be modified in several ways, such as using strips mounted edge on instead of wires or using waved strips extending in the same direction and joined to make a honeycomb pattern. The movement of the grid may be in a single direction only if that is sufficient to eliminate the shadows. The design of the telecentric electron lens system 8 can take any of a number of forms, such as those described in US Patent Specifications 4 039 810, 4 140 913, 4 164 658 and 4 238 680. In addition the designs of the vacuum envelope 6 and the air lock 12 can be altered to suit the remainder of the processing plant for the semiconductor slices. Any suitable construction may be used for the step and repeat control of the X-Y table.

CLAIMS

1. An electron beam apparatus including an evacuated envelope containing an area photocathode, electron lens means and a workpiece, the electron lens means being arranged to focus on the workpiece an image of electrons emitted by the photocathode, an illuminated mask and an optical lens for focussing on the photocathode a light image of the pattern of the mask, thereby to cause the mask pattern to be exposed on the workpiece by an electron beam.

2. Apparatus according to claim 1 including a planar electrode parallel to the photocathode for extracting and accelerating electrons emitted by the photocathode, the electrode being foraminated and maintained at a positive potential relative to the photocathode so as to produce a uniform electric field gradient between the photocathode and the electrode.

3. Apparatus according to claim 2 wherein the planar electrode is a grid of fine metal wires and/or strips held in tension in a perimeter frame.

4. Apparatus according to claim 2 or 3 wherein the planar electrode is moved in its own plane during exposure of the workpiece so as to eliminate shadows of the electrode on the workpiece.

5. Apparatus according to claim 4 wherein the planar electrode is moved continuously in a cyclic manner during exposure of the workpiece.

6. Apparatus according to any preceding claim wherein the electron lens includes electron beam deflection means responsive to signals from electron detectors picking up secondary or backscattered electrons from the workpiece to align the electron image with a particular part of the workpiece.

7. Apparatus according to claim 6 in which an alignment mask is placed in the light optical path whilst electrical signals for the electron beam deflection means to produce the required alignment are established, the electrical signals being maintained after the alignment mask is removed and during exposure of the workpiece.

8. Apparatus according to any preceding

claim wherein the workpiece is mounted on a table capabl of movement in two directions enabling different areas of the workpiece to be exposed sequentially to the focussed electron image.

9. Apparatus according to any preceding claim wherein the illuminated mask is a reticle on glass or quartz bearing a pattern which is several times the size of the pattern to be exposed on the workpiece and the light optical system and the electron optical system together produce the required size reduction.

10. Apparatus according to claim 9 wherein the light optical system produces an image of the same size as the pattern on the reticle and the electron optical system produces all of the size reduction required.

11. Apparatus according to any preceding claim wherein the evacuated envelope has an air lock for enabling workpieces to be inserted and extracted, vacuum pump means being provided to sustain the vacuum in the envelope.

12. Apparatus according to any preceding claim wherein the workpiece is a semiconductor slice having a coating of electron bombardment sensitive resist, whereby the apparatus is used in the manufacture of one or more integrated cicuits on the slice.

13. Electron beam apparatus substantially as described herein with reference to the accompanying drawings or modified as described.

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